State of California
Department of Industrial Relations
Division of Occupational Safety and Health

Memorandum

Date: March 20, 2019

To: Christina Shupe, Executive Officer
Occupational Safety and Health Standards Board
2520 Venture Oaks Way, Suite 350
Sacramento, CA 95833

From: Eric Berg, Deputy Chief *Eric Berg*
Research and Standards Unit
Division of Occupational Safety and Health

Subject: Evaluation of Petition No. 571 to amend title 8 section 3441

1.0 INTRODUCTION

On November 27, 2018 the Division of Occupational Safety and Health (Cal/OSHA) received a petition from Michael Pankonin (petitioner) of the Association of Equipment Manufacturers (AEM). AEM represents over 1000 firms that either manufacture or directly support the manufacture of mobile off-road machines including agricultural equipment.

The petitioner is requesting a change to title 8 section 3441, Operations of Agricultural Equipment, to permit the use of highly automated and autonomous agricultural equipment (HAAAE) without an operator on the equipment or at the controls when the equipment is used in accordance with the manufacturers' instructions and guidance.

Labor Code Section 142.2 permits interested persons to propose new or revised standards concerning occupational safety and health, and requires the Occupational Safety and Health Standards Board (Standards Board) to consider such proposals and render a decision no later than six months following receipt.

California Labor Code section 147 requires the Standards Board to refer to Cal/OSHA for evaluation any proposed occupational safety and health standard. Cal/OSHA is required to submit a report on the proposal within 60 days of receipt.

2.0 BACKGROUND INFORMATION ON HIGHLY AUTOMATED AND AUTONOMOUS AGRICULTURAL EQUIPMENT (HAAAE)

HAAAE, within the context of this petition, are self-driving agriculture vehicles that have the ability to navigate and avoid collisions without an operator riding on the vehicle or directly controlling the vehicle. The vehicles navigate and avoid collisions using a computer that assimilates information from a combination of sensors mounted on the vehicle. HAAAE have the ability to observe real-time conditions and react to the conditions without human intervention. HAAAE are assigned a task and they perform

them autonomously. HAAAE technology can be retrofitted to any agricultural vehicle performing any agricultural task.

3.0 PETITIONER'S REQUEST AND BASIS TO AMEND TITLE 8 REGULATIONS

The petitioner requests an addition to subsection 3441(b) to allow the operation of self-driving HAAAE with human detection/avoidance capabilities. The petitioner contends that subsection 3441(b) currently prohibits self-driving HAAAE.

The petitioner asserts there have been many design efforts directed toward developing HAAAE and the resulting advancements in technology have made it safe for persons to work in close proximity to HAAAE. The petitioner also believes the use of HAAAE in California will increase agriculture production output.

4.0 SECTION 3441(b) REQUIREMENTS AND PROPOSED AMENDMENTS

Subsection 3441(b) currently requires self-propelled equipment to have an operator stationed at the controls on the vehicle or positioned at an alternate location that has the proper controls. The subsection also allows operators to be off of certain slow moving furrow guided vehicles, if the operator is within easy reach of the controls. The petitioner is correct that subsection 3441(b) does not permit use of computer controlled self-driving HAAAE.

The additions proposed by the petitioner to expressly allow for self-driving computer-controlled HAAAE are shown below in underline-strikeout format.

General Industry Safety Orders
Group 3. General Plant Equipment and Special Operations
Article 13. Agricultural Operations
§3441. Operation of Agricultural Equipment.

* * * * *

(b) All self-propelled equipment shall, when under its own power and in motion, have an operator stationed at the vehicular controls. This shall not prohibit the operator occupying or being stationed at a location on the vehicle other than the normal driving position or cab if controls for starting, accelerating, decelerating and stopping are provided adjacent and convenient to the alternate position. If the machine requires steering other than ground or furrow steering or operates at ground speeds in excess of two miles per hour, steering controls shall also be provided at the alternate location. Seedling planters and other similar equipment traveling at a speed of two miles an hour or less where a control that will immediately stop the machine is located at the operator's work station will satisfy this requirement.

(1) Furrow guided self-propelled mobile equipment may be operated by an operator not on the equipment provided that all of the following are complied with:

(A) The operator has a good view of the course of travel of the equipment and any employees in the immediate vicinity.

(B) The steering controls, when provided, and the brake and throttle controls are extended within easy reach of the operator's station.

(C) The operator is not over 10 feet away from such controls and does not have to climb over or onto the equipment or other obstacles to operate the controls.

(D) The equipment is not traveling at over two miles per hour ground speed.

(2) Highly automated agricultural equipment and autonomous agricultural equipment may be operated by an operator not on the equipment provided that it is used in accordance with manufacturers' instructions and guidance.

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5.0 APPLICABLE FEDERAL OSHA REGULATIONS

The federal OSHA regulations do not have an equivalent or similar requirement for operators of agricultural equipment to be stationed on the equipment or an alternate control location as required by title 8 section 3441(b).

6.0 APPLICABLE CONSENSUS STANDARDS

6.1 International Standards Organization

The International Organization for Standardization (ISO) addresses HAAAE[1] in ISO Standard 18497 *Agricultural Machinery and Tractors – Safety of Highly Automated Agricultural Machines – Principles for Design* (First edition, 2018, see Attachment 1). Examples of HAAAE cited in ISO 18497 are agricultural tractors, tractor implement systems, implements, and self-propelled machinery.

ISO 18497 is a performance-based standard that specifies the principles in the design of HAAAE to achieve safe operation. To be compliant with ISO 18497, HAAAE must contain all of the following incorporated into their design:

- A perception system capable of detecting and locating persons or other obstacles relative to the machine;
- A perception system capable of locating and positioning the HAAAE to prevent unintended excursions beyond the boundary of the working area;
- Be able to ensure that there is no obstacle in the hazard zone prior to moving;
- Give audible or visual alarms and enter its defined safe state when an obstacle is detected or an obstacle enters its hazard zone;
- Have the means to enable a local or remote operator to stop or start highly automated operation; and
- Allow for adequate supervision by a local or remote operator.

6.2 Society of Automotive Engineers

The Society of Automotive Engineers (SAE) publishes Recommended Practice J3016-2018, *Taxonomy And Definitions For Terms Related To Driving Automation Systems For On-Road Motor Vehicles* (see Attachment

[1] The ISO Standard uses the term highly automated agricultural machine (HAAM) in lieu of HAAAE. HAAM and HAAAE, for purposes of this evaluation, are identical.

2). The document covers automated on-road vehicles, more commonly known as self-driving cars. HAAAE relies on similar positioning and detection technology to that in self-driving cars.

SAE J3016 provides detailed definitions for the six levels of driving automation and describes motor vehicle driving automation systems.

The SAE J3016 automation levels start at zero where a human is the full time driver and directly controls the vehicle. The levels of automation progress to level 5 where the vehicle performs full automation driving. SAE J3016 can be used to classify types of HAAAE since no other document exists to classify automated agricultural equipment.

7.0 HAZARDS TO WORKERS IN PROXIMITY TO HAAAE

In California, there are a variety of agricultural activities that require employees to work in proximity to agricultural equipment such as tractors and harvesters. Harvesting of crops such as lettuce, broccoli and corn and laying irrigation lines all require employees to walk alongside tractors and other mobile equipment. This exposes employees to the hazard of being struck or run over by agricultural equipment which can result in serious and fatal injures including:

- Fractures
- Crushing injuries
- Amputations
- Contusions
- Abrasions

8.0 TELEPHONIC CONFERENCE WITH NIOSH

Cal/OSHA conducted a telephonic conference with a representative from the National Institute for Occupational Safety and Health (NIOSH). NIOSH employs a group of researchers at the Center for Occupational Robotics Research (CORR) dedicated to understanding the hazards and preventing injuries associated with robotics and automated machines such as HAAAE.

Currently, CORR has limited data available because HAAAE is an emerging technology and its use is not widespread. CORR recommended Cal/OSHA review Recommended Practice SAE J3016 discussed in part 6.2 of this evaluation.

CORR is closely observing and following the development of automated agricultural equipment while the industry gains experience. Although the CORR representative cautioned that there is currently a lag in the implementation of safety devices to protect workers near automated machinery, the representative declined to provide an opinion as to whether HAAAE could be used safely in the agricultural industry.

9.0 PETITIONER NOT ABLE TO PROVIDE ADDITIONAL REQUESTED INFORMATION

Cal/OSHA requested the following information about HAAAE from the petitioner:

1. A copy of an equipment manufacturer's instructions and guidance

2. Specific crops for which HAAAE would be used
3. Type of agricultural operations where HAAAE would be utilized
4. Initiation of product development for HAAAE
5. A history of product development milestones
6. Length of time HAAAE has been used commercially
7. Locations in the United States and worldwide where HAAAE are currently being used commercially
8. Data of human injury during product development and commercial use of HAAAE

The petitioner did not provide any of the requested information to Cal/OSHA. In a follow-up telephone conversation, the petitioner explained that none of the requested information was available because the data did not exist and there were no HAAAE in existence that was functional in accordance to the ISO 18497 standard.

10.0 FIELD EVALUATIONS

Field evaluations of HAAAE and technology relevant to HAAAE were conducted at the Biological and Agricultural Engineering department of University of California in Davis, CA and Monterey Mushroom, Inc. located in Watsonville, CA. The following are summaries of these evaluations.

10 .1 University of California, Davis

The Division contacted Professor Stavros Vougioukas of University of California Davis (UC Davis) who conducts research and development in the Biological and Agricultural Engineering program and specifically in automated agricultural equipment. On February 25, 2019, two prototype self-driving agricultural vehicles were observed on site, a vehicle for transporting personnel, and one used to transport strawberries. Both vehicles can operate autonomously on a mapped path of travel using an on-board computer program to analyze sensors mounted on the vehicles. The sensors mounted on the vehicles are a combination of the following:

1. RTK-GPS (real time kinematic-global positioning system)
2. Three-dimensional cameras
3. LIDAR[2] (light detecting and ranging) pulsed laser light reflected off an object, return time of pulse is measured to determine distance)

The function of the vehicles and on-board navigation and anti-collisions systems were discussed with Professor Vougioukas as was the SAE J3016 standard. Professor Vougioukas commented that, in certain instances, such as if an employee fainted or stepped out from behind a tree, it is not certain that the current technology would be reliable enough to prevent an injury from occurring. He further commented that weather conditions can affect the functioning of RTK-GPS and LIDAR sensors and that the three-dimensional cameras need sufficient light to operate properly.

Professor Vougioukas opined that for the agriculture industry as a whole, a human driver is needed to ride on self-driving vehicles to intervene when necessary to prevent collisions or other unsafe operations. Additionally, professor Vougioukas commented that autonomous vehicles using the above sensors to avoid

[2] LIDAR is ranging system to measure distance using a pulsed laser that is measured as it is reflected off an illuminated target.

colliding with workers on foot "is not a solved problem" and that better sensors are needed because they are currently not 100% reliable.

10.2 Monterey Mushroom Inc, Field Survey

On February 27, 2019, the Division attended a demonstration of the Hit-Not Proximity Detection System at a Monterey Mushroom, Inc. facility in Watsonville, CA. The purpose of the visit was to observe one type of technology used to prevent collisions between vehicles and humans. The facility was testing the detection system because of a 2018 fatality accident between a large vehicle and a worker on foot. The vehicles were not autonomous or highly automated, but under the control of drivers.

The Hit-Not system uses a low-frequency magnetic field generator placed on a vehicle or moving equipment. Pedestrians in the vicinity wear receivers equipped with alarms. When a pedestrian is within a pre-set distance of a vehicle, the Hit-Not system alerts both the vehicle driver and the pedestrian with visual and audible alarms.

The Hit-Not system was observed to function properly and appears to add an additional level of protection to help prevent vehicles from colliding with pedestrians. Although Cal/OSHA is not aware of this technology being used on HAAAE, it could improve the safety of HAAAE when it is used in conjunction with other technologies.

11.0 ANALYSIS: LACK OF SUFFICIENT DATA DEMONSTRATING THE SAFETY OF HAAAE

Although great strides have been made in the development of HAAAE, it is still an emerging technology. There is very little data available to establish a solid safety record for the operation of this equipment. The petitioner did not provide substantive information to support their petition and did not demonstrate that HAAAE is safe.

Cal/OSHA's research found that the technology for operation of HAAAE is not proven to be safe. Weather and lighting conditions can adversely affect the location sensors and equipment such as GPS, LIDAR and 3-D cameras utilized on HAAAE. Based on discussions with experts in the field, the collision prevention technology currently equipped on HAAAE has not yet been perfected and will not prevent injuries to employees working in proximity to HAAAE under all likely working conditions. In addition, existing technology that could improve the safety of HAAAE, such as the use of low frequency magnetic field generators and receivers, is not used by existing HAAAE.

Although consensus standards, such as ISO 18497 and SAE J3016, can provide a foundation for the design and manufacture of HAAAE, no equipment was identified that complies with these standards.

Cal/OSHA believes that the petition is premature. The petitioners should reapply when they can provide comprehensive performance data that conclusively demonstrates that HAAAE is safe and that HAAAE conforms with the applicable consensus standards.

12.0 CONCLUSION – THE PETITION SHOULD BE DENIED

Cal/OSHA reviewed the petitioner's proposed changes to title 8 section 3441(b). The review included information provided in the petitioner's application, applicable consensus standards and communications with experts in the field of autonomous equipment. Field evaluations were also conducted at two different locations that employ technology relevant to the use of HAAAE.

Based on the information gathered during the evaluation, Cal/OSHA recommends the Occupational Safety and Health Standards Board deny this petition.

cc: Yancy Yap
Jason Denning